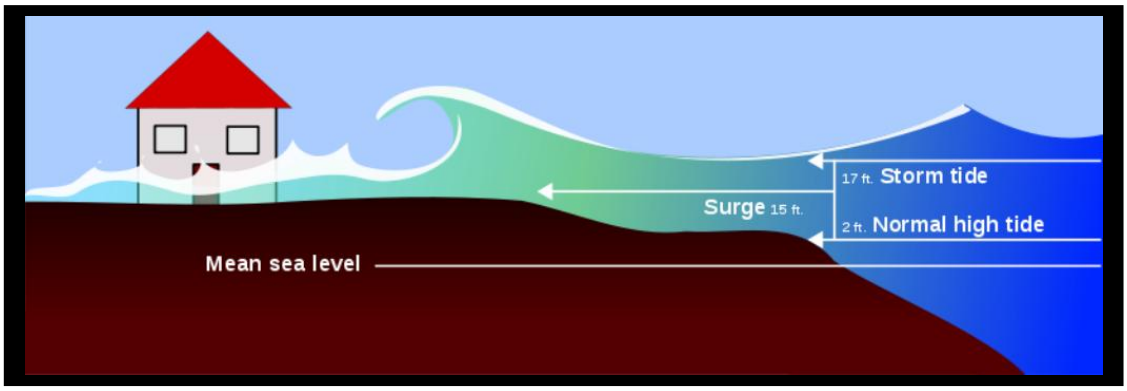
Basic Plan - Appendix I

HURRICANE HAZARDS

I. Hazards

The three major hazards produced by a hurricane are the storm surge, high winds including tornadoes, and rainfall. Of these, storm surge is by far the most dangerous, historically causing nine out of ten hurricane-related deaths. The high winds of a hurricane can also have a devastating effect on persons outdoors or inside unsound structures during the passage of the storm. Finally, rainfall may inundate potential evacuation routes and prevent persons from evacuating areas vulnerable to the storm surge if they do not evacuate in a timely manner.

A. Storm Tides & Wave Heights



1) Storm tides and floods account for most of the deaths and much of the devastation associated with hurricanes. The storm "surge" is the difference between the storm-induced water level and the normal water level. The storm surge is a large dome of water often 50 to 100 miles wide that sweeps across the coastline near where the hurricane makes landfall. The surge of high water topped by waves is devastating. The shallower the coastal water, the higher the surge. Depending on the configuration of the shore and ocean bottom, the storm surge may reach heights of eighteen feet or more above the normal *(astronomical)* tide level along Virginia's coast. Many factors influence the degree of storm surge. These include the intensity of the hurricane, its size, its forward speed, bottom conditions where the surge comes ashore, the position or angle of the hurricane's track as it crosses the coastline, and the physical configuration of the coastline where the surge comes ashore.

2) The more intense the hurricane, the higher the surge will be. Generally, shallow water locally off a coast where the hurricane comes ashore increases the surge height. Also, the closer to perpendicular that the track of the hurricane follows in relation to the coastline, the higher the surge will be. The presence of a major bay, inlet, or river mouth where the surge comes ashore can greatly amplify the height of surge as it travels with a "funneling effect" from the bay or river mouth to the back of the bay or up the river.

3) The second important effect of the storm surge is its ability to inundate coastal roadways and areas subject to tidal flooding hours before the eye of the hurricane actually makes landfall *(eye landfall)*. It is for this reason that all evacuation activities should be completed prior to the arrival of tropical storm force winds, 34 knots or 39 mph.

Examples of Historical Storm Tide Elevations

Top High Water Events – Sewells Point
Updated 12/2/2009 and verified by NOS

Date	Storm Name or Type	Above MLLW (1983-2001)
August 23, 1933	Hurricane (unnamed)	8.02 feet
September 18, 2003	Hurricane Isabel	7.89 feet
November 12, 2009	Nor'easter	7.75 feet
March 7, 1962	Ash Wednesday Storm	7.22 feet
September 18, 1936	Hurricane (unnamed)	6.72 feet
November 22, 2006	Thanksgiving Nor'easter	6.63 feet
February 5, 1998	Twin Nor'easter (#2)	6.58 feet
October 7, 2006	Columbus Day Nor'easter	6.52 feet
April 27, 1978	Nor'easter	6.41 feet
April 11, 1956	Nor'easter	6.32 feet
September 16, 1933	Hurricane (unnamed)	6.12 feet
January 28, 1998	Twin Nor'easter (#1)	6.04 feet
September 16, 1999	Hurricane Floyd	5.97 feet
September 27, 1956	Hurricane Flossy	5.92 feet
September 12, 1960	Hurricane Donna	5.92 feet

Hazards – Continued

B. High Winds

1) High winds also render certain segments of the population vulnerable to the passing hurricane and those persons should be evacuated. This hazard applies to residents of structures unable to withstand the stress and uplift forces from hurricane force winds. Hurricane force winds are defined as winds with a maximum sustained velocity exceeding 74 miles per hour *(mph)*. Hurricane winds have been recorded as high as 190 mph. The storm system may also cause tornadoes with even higher winds that, over a small area, can be even more destructive, causing extensive damage to buildings and loss of life.

2) Mobile homes are particularly susceptible to hurricane force winds. Mobile homes are lightweight construction, with generally flat sides, roofs and ends. Because of these characteristics, the winds of hurricanes can toss mobile homes around, rolling them over and over to complete destruction. In addition, even a mobile home that is not overturned is quite vulnerable to smashing from other neighboring mobile home units rolling into it. Although local regulations require that mobile homes be anchored to withstand high winds with frame tie-downs, anchorage system requirements usually are designed to withstand a wind velocity of from 70 to 110 mph. Because hurricane winds can reach 190 mph, the National Weather Service recommends that all residents of mobile homes evacuate to a more sound structure when threatened by the direct hit of a hurricane.

3) The high winds hazard must be considered as to its predicted extent of effect, but also its timing effect. Dangerously high winds usually arrive at the coastline hours before the eye of a hurricane makes landfall.

4) Evacuation activities cannot be safely carried out after the arrival of sustained tropical storm force winds *(34 knots or 39 mph including significantly higher gusts)*. Therefore, all evacuees should have completed their movement to the destinations before the arrival of sustained tropical storm force winds.

5) Tropical cyclone systems *(tropical storms & hurricanes)* often spawn tornadoes when certain instability and vertical shear conditions exists, in a manner similar to other tornado-producing systems. However, in tropical cyclone systems, the vertical structure of the atmosphere differs somewhat from that most often seen in mid-latitude systems. Because the vertical shear in tropical cyclones is also very strong at low altitudes, the combination of instability and shear can become favorable for the production of small super-cell storms, which have an enhanced likelihood of spawning tornadoes compared to ordinary thunderstorm cells.

Hazards – Continued

C. Rainfall

1) The National Oceanic & Atmospheric Administration *(NOAA)* Hydro meteorological Prediction Center *(HPC)* provides forecast, guidance, and analysis products and services to support the daily public forecasting activities of the National Weather Service *(NWS)* and provides tailored support to other government agencies in emergency and special situations.

2) Forecasters at the HPC have been issuing Quantitative Precipitation Forecasts *(QPFs)* since 1960. The HPC also works in conjunction with meteorologists in the National Environmental Satellite & Information Service *(NESDIS)* Synoptic Analysis Branch *(SAB)* to obtain information regarding precipitation and moisture availability estimates. On average, the amount of rainfall from a tropical cyclone can be "estimated" by dividing 100 by the forward speed of the storm which equals the estimated number of inches rainfall associated with the storm. *(100 ÷ forward speed = estimated rainfall in inches)*

3) Rainfall does not normally necessitate the emergency evacuation of large numbers of residents during the passage of a hurricane, as does the storm surge. However, it may cause the early inundation of roadways utilized as evacuation routes. Rainfall from a hurricane, if preceded by a recent wet weather period, may increase the risk of river flooding in areas usually not impacted by hurricanes, and can also increase the potential for flash flooding.

4) Even though rainfall normally does not directly cause loss of life, freshwater inundation of roadways preceding hurricane eye landfall could well cause the severing of evacuation routes, adding critical hours to the overall evacuation time.

II. Historical Hurricane Activity

Continuous weather records for the Hampton Roads Area of Virginia began on January 1, 1871 when the National Weather Service was established in downtown Norfolk. The recorded history of significant tropical storms that affected the area goes back much further.

Prior to 1871, very early storms have been identified in ships logs, newspaper accounts, history books, and countless other writings and photos. Those that used to live along the barrier islands all knew of the horrors of a hurricane landfall.

During Colonial times, the residents of coastal Virginia were a people that lived near the water and largely derived their livelihood from the sea. The original settlers at Jamestown knew hurricanes firsthand. It is thought that the lost colony of Roanoke Island *(classified during colonial times as a Virginia Colony)* may have been doomed by such a storm. It has been debated that the ancestors of the horses of Chincoteague were from a Spanish Galleon that wrecked during a coastal storm.

Historical Hurricane Activity – Continued

On average, two tropical storm systems, or their remnants, impact the Commonwealth yearly, with hurricanes expected once every 2.3 years. These averages are competitive to what is seen along the Gulf coast, even though major hurricanes are far rarer in the northern latitudes. Local histories and shipwreck books have proven to be an invaluable resource for narrowing down the dates of some of the more ancient tempests.

Fortunately, Virginia is far enough to the north that Category 5 hurricanes have not threaten the coast. Only one major hurricane is known to have impacted Virginia since 1900 due to the orientation of the Virginia coast. Tropical storm systems usually move northward as they cross the latitude of the Mid-Atlantic. However, most every tropical cyclone that has struck the southern United States has negatively impacted the weather across Virginia, sometimes leading to disastrous consequences.

An average of two hurricanes each year comes close enough to affect Virginia. The five most destructive and deadliest hurricanes impacting Virginia in modern times were:

- Chesapeake-Potomac Hurricane, August 1933 *(Category 2 in VA)*
- Hurricane Hazel, October 1954 *(Category 1 in VA)*
- Hurricane Camille in August 1969 *(Tropical Depression in VA)*
- Hurricane Floyd September 16, 1999 *(Tropical Storm in VA)*
- Hurricane Isabel September 18, 2003 *(Tropical Storm in VA)*

The August 1933 hurricane moved from the southeast and made landfall as a Category 2 hurricane south of Norfolk and Virginia Beach. Tides in Norfolk were reported to be 9.7 feet above mean low water *(the average height of the low water over a 19 year period)*. Virginia suffered 18 fatalities and damages of $79 million were reported.

In October 1954, Hazel made landfall south of Wilmington North Carolina as a Category 4 hurricane. Hazel maintained Category 1 hurricane force winds as it moved north through central Virginia. Widespread damage occurred, an estimated $25 million dollars were reported. There were 13 storm related fatalities in Virginia.

Camille made landfall along the Mississippi coast as a Category 5 hurricane on August 17, 1969. Camille entered Virginia on August 19th as a tropical depression, and brought torrential rainfall. Nearly 31 inches of rain fell in a 12 hour period resulting in flash floods and mudslides that killed 153 people. The majority of the deaths occurred in Nelson County where 113 bridges washed out. Damage was estimated at $113 million.

Floyd made landfall on September 16, 1999 near Cape Fear North Carolina as a Category 2 hurricane. Floyd weakened as it tracked through coastal North Carolina into Virginia dumping 10-20 inches of rain, in addition to the 10 inches received in the previous 10 day period from Hurricane Dennis. The City of Franklin and Southampton, Surry and Isle of Wight Counties were hardest hit. The City of Franklin experienced major flooding from the swollen Blackwater River. There were 4 storm related deaths in Virginia. Storm damage in Virginia totaled in excess of $255 million with 64 jurisdictions affected.

Historical Hurricane Activity – Continued

Isabel made landfall near Ocracoke, North Carolina as a strong Category 2 hurricane on September 18, 2003. Isabel quickly weakened as it tracked through coastal North Carolina and entered Virginia as a strong tropical storm delivering Category 2 storm surge damages. Isabel caused major power outages across the Commonwealth and significant surge flooding along the lower Chesapeake Bay and its tributaries. There were 36 storm related fatalities in Virginia. Virginia reported damage of over $625 million with 100 of its 135 localities declared major disaster areas.

Historical Storm Track Display Graphic